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ABSTRACT

This report acknowledges the problems faced by industrial/organizational psychologists who must make personnel decisions involving physically demanding jobs. The scarcity of criterion-related validation studies and the difficulty of generalizing validity are considered, and a model of physical performance that builds on Fleishman's (1984) taxonomic work is described. Seven constructs of the model are defined within the context of three broad dimensions of performance: muscular tension, power, and endurance make up the muscular strength category; the cardiovascular endurance category is undivided; and flexibility, balance, and neuromuscular integration comprise the movement quality category. Examples of where each construct is important for performance are provided. Several hypotheses about the interrelationships among the constructs are presented. Finally, three sources of empirical support for the model are summarized: (1) an analysis of the physical demands of over 2,000 tasks from approximately 200 jobs, with results summarized in relation to the three major dimensions of the model; (2) an analysis of test scores from 12 studies concerned with occupational performance of adults, in which the 7 physical performance constructs of the model could account for all the interpretable factors identified across the studies; and (3) a compilation of tests from 8 studies that validated the tests as predictors of job performance and revealed that the tests were measures of muscular strength, cardiovascular endurance, balance, flexibility, and coordination. A four-page reference list is appended. (NRB)

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A MODEL OF PHYSICAL PERFORMANCE FOR OCCUPATIONAL TASKS

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Although I/O psychologists bear the responsibility for personnel decisions involving physically demanding jobs, the conceptual base from which they must work is considerably underdeveloped. Major problems exist currently in the analysis, definition, and classification of physical performances. There are a number of reasons that contribute to this state of affairs. However, given the breadth of the historical assessment data base and the testing research in industry over the past ten years, it is now appropriate to reformulate a model of physical performance.

Since the beginning of modern testing, assessments of physical capacities and performances have been used. Three schools of thought influenced the study of physical performances in industry. First in 1882, Sir Frances Galton established an anthropometric laboratory for the performance of strength, reaction time, and movement time measurements. He was followed by James Cattell who also administered physical tests which included measures of strength, movement speed, kinesthesis, and reaction time. Use of these measures by both Galton and Cattell was driven by conceptual reasons as they sought to understand human intellectual functioning. A second influence over the years is the extensive measurement base which has evolved from the work of exercise physiologists and physical educators as part of fitness and

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motor skills evaluations. In the United States, David Brace and Frederick Rand Rogers provided one of the first scientific measurement bases for physical performance. This research was stimulated by national concerns for physical fitness of military personnel and American youth. A third historical influence on the study of physical performance is from the work of the early industrial engineers who sought to improve work efficiency by redesign of tools and work methods. Detailed analyses of work postures, object handling, and fatigue have contributed both directly and indirectly to the measurement of physical performance. Assessments have always been targeted at workplace performance and the measures of movement time and motions are fundamental to many of our current investigations.

Over the past decade, industry has relied upon physical performance research to provide assessments of job requirements and applicant capabilities for purposes of personnel selection. A concern of employers whose jobs are physically demanding is that job performance requirements are met while maintaining the well-being of the worker. It is increasingly apparent that physically unfit workers and individuals working at their maximum capacity are at higher risk of accidents and injuries than those who are physically qualified (Chaffin, 1974; Chaffin, Herrin & Keyserling, 1978; Kemp, 1981; Keyserling, Herrin & Chaffin, 1980). Also equal employment opportunity legislation and its enforcement have heightened employers' responsibilities to select applicants fairly including women and

qualified handicapped individuals. Establishing fair employment procedures for physically demanding jobs is a rather recent development in the United States and one that has not enjoyed overwhelming success (c.f. Arvey, 1979; Schlei & Grossman, 1976).

Compared to other types of employment testing, physical performance test validation is in infancy. There are relatively few criterion-related validation studies, and those completed are spread across different industries and jobs. The possibilities for generalizing these results (Schmidt & Hunter, 1977) will quite possibly not be realized for some time. Guion's (1976) concern that selection research is technologic and situational is a relevant criticism. This research should, according to Guion, evolve a set of generalizations transcending specific jobs or tasks. To date, very little has been published which studies physical performance for occupational tasks.

There are a number of ways to approach the problem of generalizing validity (Guion, 1976), however a method that seems most promising for physical performances is the development of a taxonomy. Fleishman's (1984) recent book on taxonomies of human performance is most instructive and provides us with a starting point. I believe this work serves as a transition piece from the study of physical fitness to the study of occupational performance.

I want to describe a model of physical performance that builds on the taxonomic work of Fleishman and takes us to the next stage in the evolution of this research. I will take time to define constructs of

the model and provide examples where the construct is important for performance. I will present hypotheses about the interrelationships among the constructs and finally I will summarize three sources of empirical support for the model.

Selection and Definition of Physical Performance Constructs

As a result of research over the past five years, we can specify physical performance dimensions that form a comprehensive, yet efficient structural model for studying jobs and tasks. The first step involved identifying candidate factors, dimensions, components, and abilities associated with physical performance in the research literature. The second step required selecting and defining performance constructs to form the categories of the model. The third step involved devising predictions of the relationship among the constructs of the model.

In the process of identifying existing dimensions of physical performance, one quickly discovers a wide array of concepts and categories many of which are either overlapping and derivitive or highly specific. Existing physical fitness test batteries and their dimensionality have been developed either through factor analytic techniques (Fleishman, 1964; Harris, 1969; Jackson, 1971) or rational evaluation of human work and fitness capacity. There is a need to merge physiological definitions with factorially derived categories in order to provide a standard and comprehensive set of dimensions for the study of occupational performance.

We selected three broad dimensions and within these, seven constructs to represent comprehensive coverage of the physical performance domain. The following criteria were used: (1) recognized research history as a component of a relevant taxonomy; (2) definition consistent with human physiological categories; (3) measurement resulting in sufficient individual variability; (4) generality across occupational tasks. The three broad dimensions of performance are thus identified as muscular strength, cardiovascular endurance, and movement quality. These categories break down into specific smaller constructs and these are described next.

Three constructs are subsumed by muscular strength. The first is muscular tension and it is the capacity to exert tension against a resistance. It includes both isometric and isotonic muscular contractions. Isometric, which is static strength, involves application of muscular tension, but against a resistance with no resulting movement of the resistance or the joints involved. Isotonic or dynamic strength involves movement. Although physiologists distinguish rather vividly between isometric and isotonic strength, the level of analysis in the study of occupational tasks typically does not require specification of contraction type. This is because in virtually every work task that requires static strength, dynamic strength is also required to accomplish the complete task. Therefore, this muscular tension construct included both static and dynamic components within a single level of task analysis.

Muscular power, the second component of muscular strength, is the rapid use of dynamic force. The muscular power dimension encompasses muscular tension with the added factor of speed. Although Wilmore (1977) subdivides power into ballistic power and general power, it appears that general power is a sufficient construct for use in applied work settings.

The third component of muscular strength is muscular endurance. Muscular endurance is the capacity to perform tasks requiring continued localized muscular work while resisting fatigue. Muscular endurance could also be subdivided into categories static and dynamic work, but unlike athletic performances, we see few tasks requiring pure static contractual endurance in industrial settings. Two external factors that affect the individual's work capacity are workload and work duration.

Cardiovascular endurance is the second primary factor identified for the physical performance of occupational tasks. We do not find it necessary subdivide this factor into component parts such as we did with muscular strength. Cardiovascular endurance refers the capacity to sustain gross body muscular activity over prolonged periods. It is the aerobic capacity and the general systemic fitness of the individual as contrasted to muscular endurance which is localized and involves a small group of muscles and joints. Physiologists define cardiovascular endurance as the efficiency with which oxygen is delivered and used by the working muscles, and it is considered to be the most important component of performance. Workload and work duration also affect performances requiring cardiovascular endurance. Muscular work at low loads and short durations may not make any significant demands on the system; however, when load or duration increases beyond that of an isolated bout of work, it will be reflected by adjustments in respiration and circulation. As Astrand and Rodahl (1977, p. 299) note, muscular work in industrial settings is seldom maintained for continuous periods of time. However for some industrial jobs, this is simply not true (e.g. packers, warehouse personnel, pole climbers). When a job requires muscular performance capacities over time, the construct of cardiovascular endurance will be important simply because the muscles require oxygen for contraction and the vascular system delivers it.

The final primary dimension, movement quality, concerns characteristics that contribute to the degree of skilled performance. We have defined three components of movement quality that include flexiblity, balance, and neuromuscular integration; however, more factors will probably be identified as research moves forward. Flexibility is the range of motion through which a limb or lever arm can rotate. Although this is a fairly accurate definition for static flexibility, a broader concept is needed for functional flexibility in work performance. Typically, multiple joints are involved in motions used to perform tasks and assume postures. A range of motion in the knee, hip, and shoulder joints is required frequently in performaning industrial tasks. deVries (1974) considers flexibility of motion within the definition of dynamic flexibility. The ease with which a joint is capable of displacing a lever is an important facet of skilled physical performance. Functional flexibility, therefore, involves the degree to which multiple levers of the body can be displaced or rotated easily in accomplishing work while in awkward, contorted, or extended postures.

A second movement quality is that of balance. Balance is the capacity to maintain body stability under conditions where the base of support is reduced, changing, or both. O'Connell and Gardner (1972) contend the balance will be affected by either static or dynamic conditions. Balance under static conditions requires maintaining stability when exhibiting a posture or body position. This includes maintaining a pose against outside forces. The essential requirement is to place the center of gravity over the base of support so that the body's potential energy is minimized. Some action or force is required to change the body position and disrupt the static equilibrium.

Balance under dynamic conditions occurs during active physical peformance. In balancing, the center of gravity must be adjusted progressively, and coordinated with shifts in the base of support. This is facilitated by the forces generated by the body as well as by inertia. When the center of gravity does not shift over the base of support, instability results and balance is lost. The dimension of balance in the present model incorporates both static and dynamic equilibrium. This construct focuses on body stability when maintaining a single posture while resisting forces (including gravity) as well as when the body is in motion. It appears that both conditions are applicable for physical work performance.

The final component of movement quality we identified is neuromuscular integration. This is referred to as coordination, and it is the capacity to organize movements in sequence within required temporal and spatial constraints as a response to either internal or external stimuli. In the field of motor learning and motor control, this dimension might be termed anticipatory timing to external cues (i.e., projectiles, displays); it may also be self-initiated (i.e., diving, cycling). Movement sequences can involve arms and legs separately or combined, as well as limbs moving while the body is in motion or stationary. The major concerns for neuromuscular integration are not with the extent of limb and joint involvement, but with the spatial and temporal requirements that determine accurate and effective performances.

Patterns of Relationships

Most non-test physical tasks are complex particularly when they represent large portions of job or training requirements. Prediction of complex performance will require a comprehensive set of physical constructs and a means to measure them. The three primary factors and the seven constructs that emerge from them are the framework for the model. The muscular strength constructs account for forces generated; the cardiovascular endurance construct provides for sustained activity

and the movement quality constructs specify the characteristics required for skilled action. It is possible now to specify more detailed predictions from the model.

Muscular tension, muscular power, and muscular endurance are not hypothesized as orthogonal constructs; they are all part of a larger factor of muscular strength. Absolute muscular strength, which is in part related to muscle mass, is common to these definitions. A substantial relationship between assessments of job requirements and assessments of individuals' performances is predicted using measures of these muscular constructs. It is further predicted that muscular tension measures will demonstrate a stronger association with muscular endurance than with muscular power because the former involves repetition or extension of actions requiring muscular strength while the latter combines speed with muscular strength. The additional speed factor may provide some intraindividual variation particularly in light of the relative independence of the speed and strength components.

Cardiovascular endurance assessments will be associated more closely with muscular endurance measures than with measures of other constructs because these constructs have common elements of muscular activity, activity duration, and dependence on oxygen uptake as an energy source. The more localized the muscle activity, the less closely these constructs will be associated. To the degree that tasks or performances are general and involve large muscle groups (i.e., stair climbing), the stronger the predicted relationship between these

constructs.

The flexibility construct is hypothesized to be relatively independent of the strength and cardiovascular endurance constructs, although we may begin to see a slight negative relationship with some strength measures. Moreover, it may have only slight a slight positive relationship to balance and neuromuscular integration. This could be due to the co-occurrence of these constructs within work activities. Joint mobility is prerequisite for integrated actions and, although flexibility is easily increased with training, it is not clear that these improvements will result in proportional increments in other movement qualities.

It is predicted that the balance measures will be most closely associated with assessments of neuromuscular integration and largely independent of the others (except the possible flexibility relationship discussed above). Movement sequences which maintain equilibrium are similar both conceptually and operationally to those necessary for coordinated performance. Balance is heavily dependent on information transmitted through the central nervous system. It is difficult to know whether significant individual improvements in balance are possible beyond situationally specific activities.

It is hypothesized that neuromuscular integration in physical performance may be analogous to the "G" factor (Spearman, 1904) underlying intellectual performance. Neuromuscular functioning is a central nervous system phenomenon, and the speed and fidelity of the

stimulus transmission within individuals may be biologically determined. It may be related to a greater extent to the balance and flexibility constructs and to a lesser extent the strength and cardiovascular endurance constructs. Further, coordination may underly the ability to acquire technique in industrial performance, and to transfer considerable skill to new tasks with little practice.

Summary of Research Support

It will be impossible to present the data we have collected on the model in this period of time. I will summarize briefly three sources of empirical support for the dimensionality of the model and the performance constructs included. The first series of results evaluates the structure of physical requirements within tasks. We analyzed physical demands of over 2000 tasks from approximately 200 jobs (Denning, 1984; Hogan & Bane, 1983; Hogan & Pederson, 1984; Hogan, Ogden, & Fleishman, 1978). The physical profile scores from task ratings were intercorrelated and then factor analyzed. These results can be summarized with three major dimensions of the model--that is, muscular strength, cardiovascular endurance, and movement quality.

Second, we considered the structure of physical performances within people. We analyzed test scores from twelve studies concerned with occupational performance of adults (Arnold, Rauschenberger, Soubel, & Guion, 1982; Cooper & Shemmer, 1983; Denning, 1984; Frantzve, 1984; Hogan & Pederson, 1984; Hogan, Hogan, & Briggs, 1984; Hogan, Ogden, & Fleishman, 1979; Reilly, Zedeck, & Tenopyr, 1979; Robertson,

1982). Test scores within each sample were intercorrelated and the matrix was then factor analyzed. The seven physical performance constructs could account for all the interpretable factors that have been identified across studies, although within a single study, only three or four factors emerged. These accounted for a minimum of 67% and a maximum of 83% of the variance in test scores.

Finally, we compiled tests from eight studies that have been validated as predictors of job performance and classified these tests (Arnold et al., 1983; Hogan & Pederson, 1984; Hogan, Ogden, & Fleishman, 1979; Reilly et al., 1979; Robertson & Trent, 1983; Wilmore & Davis, 1979, Wunder, 1981). The studies included used either a construct or criterion-related strategy and the test samples included both male and female adults. Research came from both private and public sector organizations and included a variety of jobs and industries. Criteria included both measures of performance in training and performance on the job. Of the validated tests compiled, the overwhelming majority were measures of muscular strength and cardiovascular endurance. But, we also found tests of balance (Reilly et al., 1979), flexibility (Hogan & Pederson, 1984; Hogan, Ogden, & Fleishman, 1979) and coordination (Hogan & Pederson, 1984; Hogan, Ogden, & Fleishman, 1979) that were significantly related to the criterion measured.

To summarize if we integrate the factors from the task analysis data, along with types of test performance data, and the valid

predictors from the empirical studies, the results converge to support the model of physical performance I have described. Denning's (1984) recent research presents a specific application of this conceptual model for a wide range of occupations at DuPont.

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